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PERCUTANEOUS CLOSURE OF PATENT DUCTUS ARTERIOSUS

Surgical Specialty:	Cardiac
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Background:

- General Considerations
    - A patent ductus arteriosus (PDA) allows the shunting of blood between the systemic and the pulmonary circulations in utero.
    - The blood flows from the higher to the lower pressure system. The rate of shunt flow is directly related to the pressure differential in the systemic and pulmonary vascular beds and inversely related to resistance. Changes in pulmonary and systemic vascular resistance via oxygenation and ventilation can affect hemodynamic stability.
    - A PDA is most commonly found in premature neonates and is directly correlated to prematurity.[1]
    - Indications for PDA closure include symptomatic pulmonary over-circulation and systemic organ hypoperfusion. A hemodynamically significant PDA may require diuretic therapy and inotropes to enhance cardiac output.[1] PDA closure is a second-line treatment after failure of medical therapy.
    - Percutaneous device closure in the cardiac catheterization suite is the first choice in infants weighing > 4 kg, over surgical closure via thoracotomy. In infants < 4 kg, it is also increasingly shown to be a safer choice. With newer devices, premature infants weighing above 700 grams are eligible for PDA device closure.[2,3] See figure below. The choice of surgical versus catheter-based closure is center-specific, and it may be determined by the capabilities of a given center.
- Patient Considerations
    - Smaller premature infants have the highest risks and present the greatest technical challenges due to small patient size and comorbidities.[3]
    - Associated Comorbidities/Syndromes in neonates and infants
        - Respiratory failure and chronic lung disease: many require respiratory support including non-invasive ventilatory support, conventional mechanical ventilation, high-frequency jet ventilation (HFJV), or oscillatory ventilation.
        - Intraventricular hemorrhage
        - Necrotizing enterocolitis (NEC)
        - Anemia

Anesthetic Planning:

The plan depends on patient demographics. Older infants or children may be outpatient cases. Premature infants in the NICU are the most fragile patients; therefore, the development of multidisciplinary protocols for transport, airway and ventilatory management, and temperature conservation is highly recommended. This will facilitate periprocedural planning and decrease unnecessary patient manipulation and exposure leading to intraoperative hypothermia. [2,4]

- Pre-Anesthetic Evaluation
    - Preoperative anemia correction
    - Review of Systems:
        - Cardiovascular: echocardiographic findings, any cardiac medications
        - Respiratory: Airway and ventilatory support requirements
        - Other comorbidities: sequelae from intraventricular hemorrhage, the risk for necrotizing enterocolitis, total parenteral nutrition (TPN) complications, hepatic and renal impairment.
    - Adequate venous access for administration of blood. Neonatal PICC lines may be inadequate for resuscitation. Some institutions have policies against transfusing blood products through small PICC lines. Additional vascular access may be indicated.
    - Clarification of code status, ECMO candidacy, and surgical backup.
    - *If NICU patient* --bedside huddle to clarify individual roles of the team during transport to cardiac catheterization suite (anesthesiologist, respiratory therapist, nursing staff, technicians, others). Clarify the route of transport. Preprocedural planning should include a strategy for continuing mechanical ventilation and for maintaining perioperative normothermia.

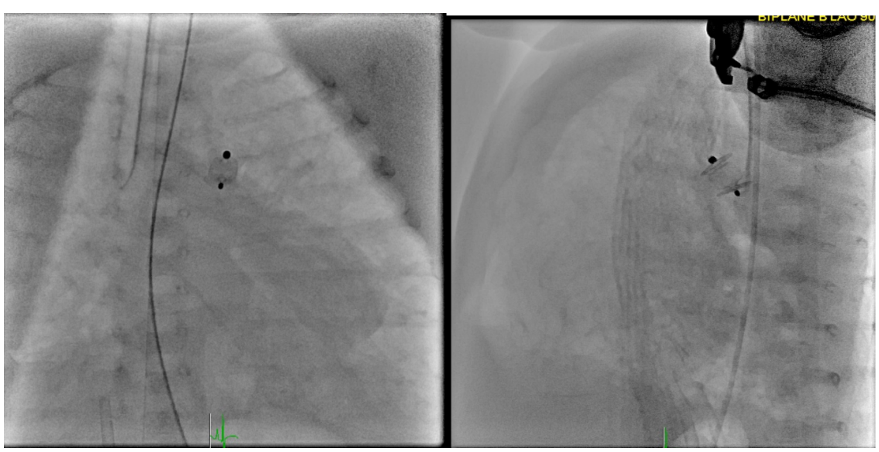
- Specific or Unique Room Set-Up Requirements:
    - *If NICU patient* --streamline processes: transport, bed transfers, mechanical ventilation, and procedure preparation and wrap up. The goal is to decrease ambient exposure to avoid hypothermia and minimize risks to the patient. [2,4]
    - If intubated- consider TIVA and use the NICU ventilator in the catheterization suite. If on HFJV or oscillator, the lab must have proper connectors ready for transfer while considering space constraints related to fluoroscopic imaging equipment.
    - If not intubated- discuss cuffed vs uncuffed ETT.
    - Continue current drips: inotropes, sedation, TPN.
    - Standard American Society of Anesthesiologists monitors, consider near-infrared spectroscopy (NIRS). Discuss with the catheterization team the need for pre- and post-ductal oximetry. Both pre- and post-ductal blood pressure (BP) monitoring should be considered. Arterial line blood pressure (BP) monitoring is not needed unless the arterial line is pre-existing.
    - Immediate RBC availability.

Intraoperative Considerations:

- General[2,4]
    - The shorter the intraprocedural time, the better. Protocols for the safest and most efficient conduct of key steps are very important.
    - Strict temperature management and monitoring: forced air warm blankets, chemical warm packs, head covering, etc.
    - Watch for reduction of diastolic BP and hemodynamic instability with anesthetic agents and increased oxygenation and ventilation.

- Induction—intravenous if NICU ventilator is used. Options include fentanyl, ketamine, benzodiazepine.
- If the patient is to be extubated, consider remifentanil with subsequent dexmedetomidine titrated at end of the case. Consider local infiltration at the puncture site for analgesia.
- Ventilation—Consider using a NICU ventilator. It maintains more precise baseline ventilatory parameters compared to the anesthesia machine ventilator. Continue baseline FiO_2 and ventilatory parameters, and adjust as needed for changes induced with anesthesia and paralytics.
- Maintenance—IV or inhalational agents, depending on what ventilator is being used.
- Be vigilant about diastolic hypotension. Maintain adequate coronary artery perfusion pressures.
- Use warmed fluids to minimize the likelihood of hypothermia, especially with premature patients.
- Hemodynamic/Physiologic goals— Note increase in diastolic BP and mean BP after PDA closure. Transient desaturation may occur as blood is shunted away from the lungs upon PDA closure.
- Consider trending NIRS as a surrogate for systemic perfusion, particularly in hypotensive or fragile patients.
- Procedural Considerations[2]
    - Positioning- arms above head.
    - Little to no contrast is used to avoid kidney injury.
    - Antibiotic prophylaxis for device placement. Caution regarding its a priori administration during cases in which successful PDA closure is mostly uncertain.
    - Femoral venous access --heparin is NOT necessary. Femoral arterial access is usually avoided.
    - TTE imaging to visualize aortic flow, left pulmonary artery flow, and occlusion of the shunt with the device in place. Post ductal cuff BP measurement to ensure no aortic obstruction.
- Emergence/Disposition – Transport to NICU intubated.
- In older infants and children, extubation and recovery in the post-anesthesia care unit or closer monitored setting as indicated.

Figure: Device shown in the ductus arteriosus after deployment: anteroposterior view (left panel) and lateral view (right panel). (Source credit: authors)



Case-Specific Complications/Pitfalls

Complications [2,3]

- Hypothermia.
- Device migration causing obstruction of the left pulmonary artery or aortic arch—retrieval in cardiac catheterization suite versus surgical intervention. This should be considered if saturations or lower extremity BPs change post-procedure.
- Iatrogenic tricuspid regurgitation due to catheter effect.
- Post-ligation cardiac syndrome. This syndrome is characterized by hypotension requiring inotropic support, and increasing oxygenation and/or ventilation requirements associated with ventricular dysfunction. It typically occurs 6-12 hours following the procedure. Although evidence is lacking, some centers prophylactically treat with calcium at the time of device deployment.

References

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